[redacted]

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 220

THE DRIFT OF AN AIRCRAFT GUIDED TOWARDS ITS DESTINATION BY DIRECTIONAL RECEIVING OF RADIO SIGNALS TRANSMITTED FROM THE GROUND.

By Edward P. Warner.

June, 1925.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 220.

THE DRIFT OF AN AIRCRAFT GUIDED TOWARDS ITS DESTINATION BY DIRECTIONAL RECEIVING OF RADIO SIGNALS TRANSMITTED FROM THE GROUND.

By Edward P. Warner.

Of the several types of radio navigation that have been considered for adoption on aircraft, one of the most attractive is that which makes use of directional reception by a loop antenna on the aircraft of non-directional waves sent out from the point towards which the aircraft is being guided. It is apparent, however, (Reference 1) that an aircraft which is kept continually headed in the direction of its destination will follow a straight course only if there is no component of wind at right angles to the intended path. A cross wind will drift an airplane sidewise and force a continual change of course until the final approach to the field will be made from directly down wind. In one sense this is not a bad thing, since it insures in the case of an airplane that approach would always be made from the direction proper for landing, but the following of a curved path increases the distance to be flown, and a type of radio navigation which forces the adoption of such a path is therefore less efficient than one which marks out a definite straight line between the point of departure and the intended destination, and holds the airplane to that line.

To determine the loss of efficiency resulting from curvature of the path calculations have been made for two particular cases by the method of step-by-step integration. The calculations have of course been based on the assumption that the pilot makes straightforward use of his radio for navigation and makes no allowance for drift. Any empirical allowance that might be made would be expected to reduce the curvature of the path and so the air distance flown.

The first case that has been assumed is that of an airplane flying a distance of 200 miles at a speed of 100 M.P.H., with the wind blowing at 50 M.P.H. directly at right angles to the course. If the course ran due north and the wind were blowing from the west the airplane would then have to head 30° west of north in order to hold to a straight line over the ground from start to finish of the flight.

Navigating by radio in the manner outlined in the first paragraph, the airplane would be headed due north at the start of the flight and would be swung around more and more to the west as the wind drifted it off to the east of the true line.

The time and components of distance covered parallel to the line connecting the points of start and finish and perpendicular to that line, these components denoted by x and y respectively, are given in Table I for the case just described and also for the case of a 20-mile cross wind acting on the same airplane, and the flight paths are plotted in Fig. 1 for the two cases.

Table I.

Airplane Flying 200 Miles at 100 M.P.H.

50-mile wind across course			20-mile wind across course		
Time (hr.)	x (distance along course)	y (drift at right angles to course)	Time (hr.)	x (distance along course)	y (drift at right angles to course)
0	0.00	0.00	0	0.00	0.00
.1	10.00	5.00	.1	10.00	2.00
.2	20.00	9.74	.2	20.00	3.89
.3	29.99	14.20	.3	30.00	5.67
.4	39.95	18.36	.4	39.99	7.34
.5	49.88	22.22	.5	49.98	8.88
.6	59.77	25.75	.6	59.96	10.29
.7	69.61	28.95	.7	69.93	11.56
.8	79.38	31.80	.8	79.89	12.68
.9	89.08	34.25	.9	89.83	13.63
1.0	98.63	36.29	1.0	99.75	14.40
1.1	108.05	37.93	1.1	109.65	14.98
1.2	117.29	39.11	1.2	119.51	15.34
1.3	126.33	39.84	1.3	129.35	15.47
1.4	135.13	40.09	1.4	139.10	15.33
1.5	143.64	39.84	1.5	148.80	14.88
1.6	151.80	39.07	1.6	158.40	14.08
1.7	159.56	37.76	1.7	167.87	12.88
1.8	166.86	35.92	1.8	177.15	11.15
1.9	173.64	33.57	1.9	186.15	8.76
2.0	179.80	30.70	2.0	194.58	5.41
2.1	185.29	27.35	2.05	198.11	2.88
2.2	190.03	23.54			
2.3	193.93	19.33			
2.4	196.93	14.79			
2.5	198.96	10.00			
2.6	199.95	5.05			

Total time = 2.70 hr. Total time = 2.09 hr.

If a straight course were being held and the drift allowed for uniformly throughout the speed along the course would be equal to the $\sqrt{V^2 - v_W{}^2}$, where V is the speed of flight and v_W the wind speed. The resultant figure would be 86.6 M.P.H., in the first case and 98.0 M.P.H. for the lower wind velocity, and the time required for the flight 2.31 hours and 2.04 hours, respectively. The following of the curved path therefore increases the time of flight and the air distance flown by 17% and 2.5% in the two cases.

The curvature of the path followed and the percentage of increase in air distance flown is independent of the length of the flight. If the distance to be covered were only 100 miles the drift would be one-half as great as that tabulated on the 200-mile flight for any given fraction of distance along the course. It is also approximately, although by no means rigorously, accurate to treat the effect of an oblique wind by breaking it up into components across and along the course, and considering the component along the course simply as increasing or decreasing the speed of flight. The last part of the path will be somewhat changed in shape if the wind is quartering instead of straight across, but the change in distance flown and in maximum drift will be inappreciable. The ratio of maximum drift off the course to the total distance between the points of departure and of arrival can then be plotted in terms of ratio of the component of wind velocity across the course to the net airspeed of the aircraft, and the percentage of increase in air distance flown as compared with that required if a continuously correct allowance for drift were made can also be plotted in terms of the same ratio. The curves are given in Fig. 2.

The maximum drift may in itself be a factor of some importance, as it may carry the aircraft over unfamiliar and dangerous country. It may, indeed, be more important than the increase of air distance and time of flight, which is unlikely to exceed 10%, as a pilot would be almost sure to make at least partial allowance for drift when flying in a cross wind having a velocity of more than a third his aircraft's speed.

Reference.

1. F. H. Engel and F. W. Dunmore : A Directive Type of Radio Beacon and its Application to Navigation. (Scientific Paper No. 480, Bureau of Standards.) 1924.

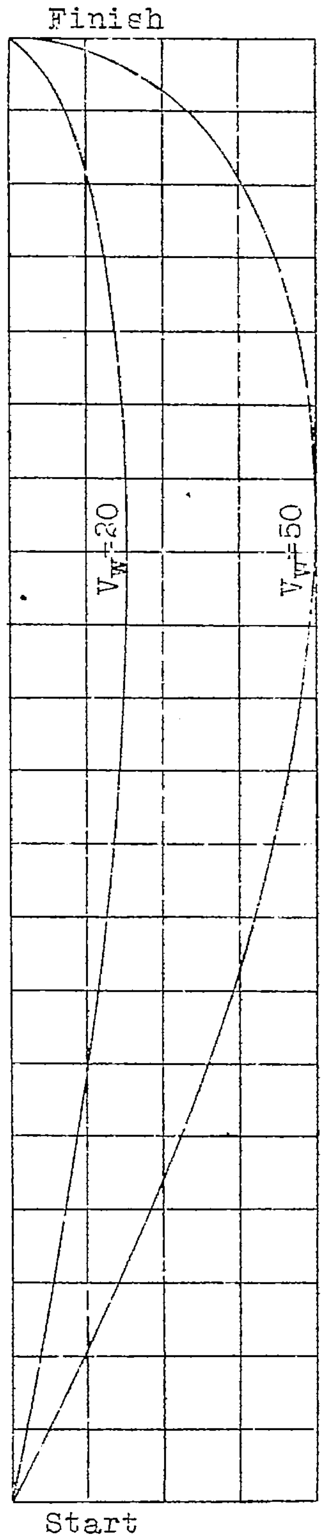
Finish
$V_w=20$
$V_w=50$
Start

Fig.1

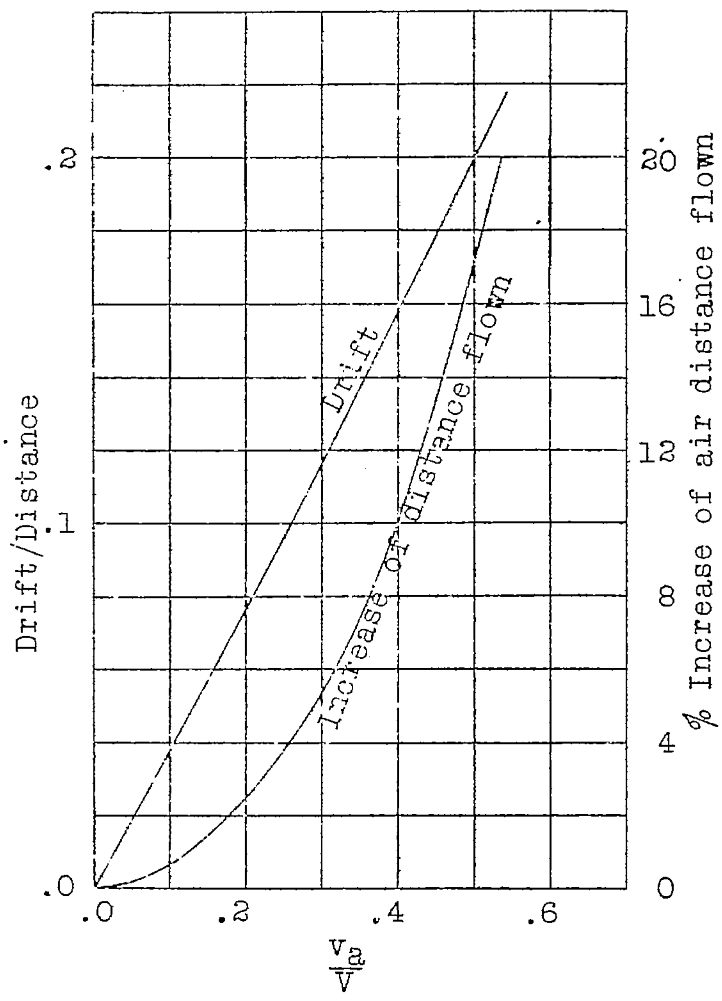
Drift/Distance
.2
.1
.0
% Increase of air distance flown
20
16
12
8
4
0
Drift
Increase of distance flown
.0
.2
.4
.6
$\frac{V_a}{V}$

Fig.2